TOWARDS THE FABRICATION OF ULTRANANOCRYSTALLINE DIAMOND NANOWIRE BASED NANOMECHANICAL SWITCHES

Kenneth J. Pérez Quintero, David Czaplewski, Anirudha V. Sumant
Center for Nanoscale Materials
Argonne National Laboratory, 9700 South Cass Ave., Argonne, IL 60439

INTRODUCTION

Nanomechanical (NEM) switches use electrostatic forces to mechanically deflect an active element into contact with an electrode, thus changing the state of the device from “off” to “on” state and vice versa. The electrostatic force is inversely proportional to the square of the gap; which makes the device increasingly effective as the gap is reduced. NEM switches are currently being studied as a complement to metal-oxide semiconductor field effect transistor (MOSFETs) switches. Complementary metal-oxide semiconductor (CMOS) technology has provided increased performance over other available technologies. However, as the dimensions of the transistors decrease, the leakage current in the “off” state increases, causing the static power dissipation to approach the dynamic power dissipation. These parasitic losses will soon result in a loss greater than 50% of the input power. (1) NEM switches have significantly reduced leakage currents, which results in reduced power consumption and improved ON/OFF ratios and they are relatively insensitive to radiation, temperature and external electric fields. Integration with MOSFETs would reduce idle power consumption of the CMOS circuits. (2)

Ultrananocrystalline diamond (UNCD) thin films, developed and patented at Argonne National Laboratory, have various interesting properties that make it an excellent candidate material for NEM switches. UNCD has negligible force of adhesion (stiction), a high Young’s modulus, low mass density, can be synthesized at low temperatures (CMOS compatible), is commercially viable and can become electrically conducting with boron doping or nitrogen incorporation. (3,4).

In this work, we demonstrate the fabrication of a UNCD nanowire based NEM switch. We aim to fabricate a reliable switch with fast switching times and low actuation voltages.

EXPERIMENTAL

We have previously fabricated horizontally aligned N-incorporated UNCD nanowires via a top-down approach using electron beam lithography (EBL) patterning and reactive ion etching (RIE) processes with lengths of 50-100 μm and widths as small as 30nm. Details about this process can be found in (5). Our switch design has a movable source anchored at both ends. An immobile drain electrode is separated from the center of the source beam by a narrow gap (80-100nm). Two electrically conducting gate electrodes are separated from the source by the gate gap, which is larger than the drain gap (6).

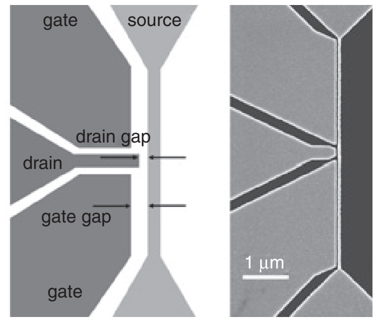

Figure 1: NEM switch design

RESULTS

We have successfully fabricated a UNCD nanowire based NEM switch using top-down approach. For maximum integration potential with CMOS technology, NEM switches need switching times comparable to FETs and the potential to operate at similar voltages (~1V). To achieve this, it is necessary to have small width, high aspect ratio wires (smaller gaps make the switch more effective, i.e. operation at lower potentials). We are currently working with the scale down of our switch to achieve the desired operating parameters.

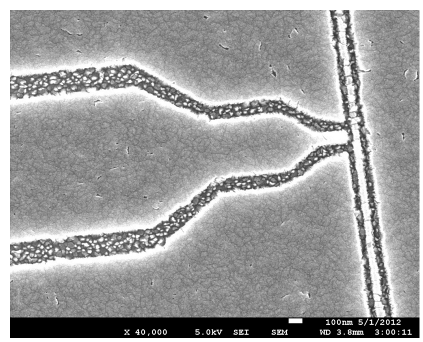

Figure 2: NEM switch SEM Image (Scale: 100nm)

ACKNOWLEDGMENTS

This work was performed at the Center for Nanoscale Materials, a U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences User Facility under Contract No. DE-AC02-06CH11357. Additional funding was provided by PR NASA EPSCoR and NASA URC Center for Advanced Nanoscale Materials at the University of Puerto Rico, Río Piedras Campus.

REFERENCES

1. Czaplewski, D. et. al. *J. Micromech. Microeng.* **19** 085003 (2009).
2. Loh, O. et. al. *Nature Nanotechnology* **7** 283 (2012)
3. E.J. Correa et. al. *Journal of Applied Physics* **102** 113706 (2007)
4. A.V. Sumant et. al. *MRS Bulletin* **35** 281 (2010)
5. Wang, X. et. al. *Nanotechnology* **23** 075301 (2012)
6. Czaplewski, D. et. al. *Electronics Letters* **45** 550 (2009)